

CAREERS THROUGH MATHS: QUANTUM PHYSICIST



JOB DESCRIPTION

A Quantum Physicist in the UK works at the forefront of technology, exploring and manipulating the fundamental principles of quantum mechanics to develop next-generation technologies. Their daily responsibilities are deeply analytical and can vary significantly depending on their sector. In an academic setting, such as the University of Oxford's Clarendon Laboratory or the University of Bristol's Quantum Engineering Technology Labs, this involves designing and running experiments on quantum systems like trapped ions or superconducting qubits, analysing complex datasets, developing theoretical models, and publishing findings. In an industrial role, for instance at companies like Quantinuum (Oxford/Cambridge) or ORCA Computing (London), the focus shifts to applied research and development, such as optimising the performance of a quantum sensor for medical imaging or debugging quantum algorithms to run on noisy hardware for a specific financial modelling application.

The work environment is highly collaborative, involving close teamwork with other physicists, engineers, and software developers. A typical day might involve writing and testing code to simulate a quantum system, meeting with colleagues to discuss the statistical results of an experiment, and preparing a presentation for project stakeholders. For those in the UK's growing quantum sector, this could mean working in a state-of-the-art commercial lab, a government-funded research centre like the National Quantum Computing Centre (NQCC) in Harwell, or remotely, developing algorithms and theoretical frameworks.

Mathematics is the absolute bedrock of this role. It is the language used to describe quantum phenomena, from the wave functions that define a particle's state to the Hamiltonians that govern its evolution. Every prediction, simulation, and analysis is rooted in mathematical formalism. A physicist might use linear algebra to calculate how a qubit's state evolves through a series of quantum logic gates or employ complex analysis to understand the behaviour of quantum systems in the presence of noise, a critical task for making quantum computers practically useful.

HOW MATHEMATICS IS USED

- **Linear Algebra:** This is the primary mathematical framework for quantum information science. Vectors represent the state of a quantum system (e.g., a qubit being in a superposition of $|0\rangle$ and $|1\rangle$), and matrices represent quantum operations (gates). For example, a physicist at Quantum Motion in London uses tensor products to describe the state of multiple qubits in their silicon-based quantum processor and calculates the unitary matrices required to execute a specific quantum algorithm for material simulation.
- **Complex Analysis & Differential Equations:** The Schrödinger equation, a fundamental partial differential equation, governs how quantum states change over time. Solving it, often for complex-valued wavefunctions, is essential for predicting system behaviour. A researcher at the UK National Quantum Technology Hub in Sensing and Timing might solve the Schrödinger equation for an atom in a magnetic field to design a more precise quantum accelerometer for navigation in autonomous vehicles where GPS is unavailable.
- **Probability and Statistics:** Quantum mechanics is inherently probabilistic. Physicists use advanced probability theory to calculate measurement outcome likelihoods and statistical methods to analyse experimental data. For instance, at ORCA Computing, a team will run a quantum circuit thousands of times to gather statistics on its output, using techniques like Bayesian inference to mitigate errors and validate that their photonic quantum computer is functioning correctly for a client's problem.
- **Group Theory and Symmetry:** This area is crucial for understanding fundamental particles and the properties of quantum materials. Symmetry operations, described by group theory, dictate conservation laws and possible

quantum states. A theoretical physicist at Durham University might use representation theory to classify the exotic electronic states in a newly discovered 2D material, predicting its topological properties which could be useful for fault-tolerant quantum computing.

- **Statistical and Analytical Methods:** Beyond pure quantum theory, physicists employ advanced data analysis and mathematical modelling to interpret results and optimise systems. This includes using Fourier transforms to analyse signal noise in quantum sensors developed by companies like Fraunhofer UK or employing machine learning algorithms (which rely on linear algebra and calculus) to calibrate quantum hardware automatically, a key R&D focus for many UK-based quantum start-ups aiming to commercialise their technology.

KEY SKILLS & TOOLS

Skill/Tool	Application
Python (NumPy, SciPy, QuTiP)	The primary programming language for quantum research and development in the UK. Used for building and simulating quantum systems mathematically. For example, a developer at Quantinuum uses QuTiP (Quantum Toolbox in Python) to model the dynamics of a trapped-ion qubit chain and optimise gate fidelities through numerical integration of differential equations.
Qiskit or Cirq	Quantum computing software development kits (SDKs). A quantum algorithm engineer in Edinburgh uses Qiskit to construct quantum circuits (represented as matrices), simulate their execution using linear algebra operations, and then deploy them to run on real hardware via the cloud, such as that provided by the NQCC.
MATLAB/ Mathematica	Used for rapid prototyping, symbolic mathematics, and control system design. An engineer at a quantum hardware company like Riverlane (Cambridge) might use MATLAB's control toolbox to mathematically design and simulate the microwave pulses needed to manipulate a superconducting qubit with high precision.

C++ & High-Performance Computing (HPC)	Used for writing efficient, low-level code for quantum system simulations that require massive parallel processing on UK supercomputers like ARCHER2. This involves optimising complex linear algebra routines to calculate the properties of large, many-body quantum systems.
Cryogenic & RF Measurement Equipment	The physical tools of the trade. A physicist in the lab uses this equipment to take measurements (e.g., qubit resonance frequency). They then use statistical analysis and curve-fitting techniques (e.g., least-squares fitting to a Lorentzian function) on the data to characterise the quantum device's performance and identify sources of noise.
LaTeX & Technical Communication	The standard for writing papers, reports, and proposals. Essential for clearly presenting complex mathematical derivations, algorithms, and data visualisations to peers within UK research collaborations (e.g., the Quantum Hubs) and to secure funding from UKRI (UK Research and Innovation).
Version Control (Git)	Critical for collaborating on complex codebases and mathematical models within UK teams. Allows for tracking changes to simulation code, algorithm implementations, and analytical scripts, ensuring reproducibility and quality control in both academic and commercial R&D environments.

Typical Pathway: The standard pathway begins with strong GCSEs and A-Levels in Mathematics, Further Mathematics, and Physics, often at A* or A grades. This is followed by a 3-4 year undergraduate Master of Physics (MPhys) or MSci degree from a Russell Group university (e.g., Imperial College London, UCL, Bristol, Southampton) with a specialism in quantum mechanics. Entry into the field typically requires a PhD in Quantum Physics or a closely related discipline, often undertaken within one of the UK's Centres for Doctoral Training (CDTs), such as the CDT in Quantum Engineering in Bristol or the CDT in Delivering Quantum Technologies in Oxford. Entry-level positions include Postdoctoral Research Associate or Junior Quantum Scientist within academia or industry. Career progression can lead to Senior Scientist, Principal Investigator, or Technical Lead roles in companies like Nu Quantum (Cambridge) or in government labs. While not yet standard, professional registration as a Chartered Physicist (CPhys) with the Institute of Physics is a recognised mark of professional competence and can aid career development.

Industry Demand: The UK government has identified quantum technology as a critical national priority, investing over £1 billion through the National Quantum

Technologies Programme. The UK quantum sector is experiencing rapid growth, with over 90 companies and numerous academic hubs driving demand for skilled physicists. The Office for National Statistics identifies high-skilled STEM roles as a major growth area. Demand is particularly high in quantum computing hardware and software, quantum communications (e.g., with BT and Toshiba's commercial quantum-secured network), and quantum sensing for defence and healthcare applications.

Real-World Impact: Quantum Physicists in the UK are directly contributing to projects with significant societal and economic impact. This includes developing un-hackable quantum communication networks with the UK National Quantum Technology Hub in Communications, creating ultra-sensitive quantum gravity sensors from companies like RSK's Geoptic Infrastructure Intelligence for detecting underground infrastructure without excavation, and designing new quantum algorithms to simulate drug molecules for the pharmaceutical industry, a key collaboration between companies like AstraZeneca and quantum software firms. Their mathematical work is securing the UK's position as a global leader in the second quantum revolution.